

# Road Transport and Power System Scenarios for Northern Europe in 2030

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# Road Transport and Power System Scenarios for Northern Europe in 2030

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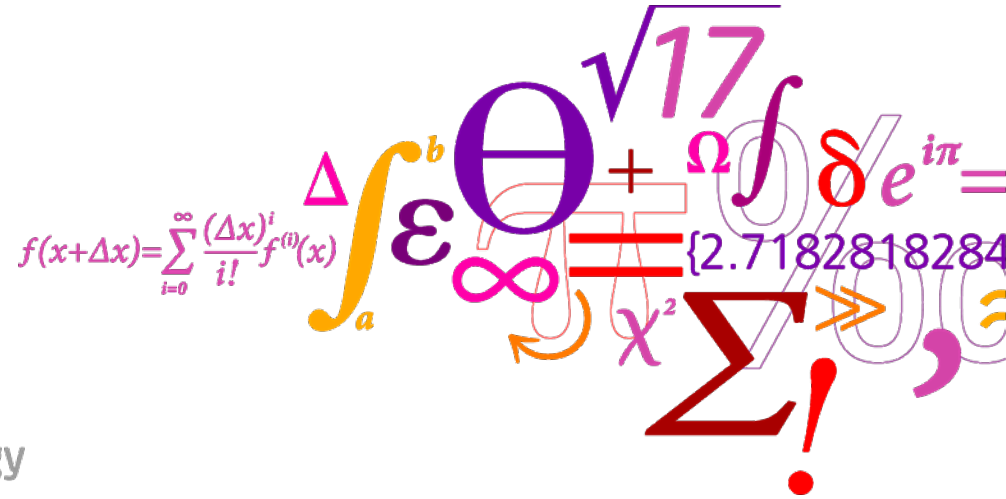



Risø DTU
National Laboratory for Sustainable Energy

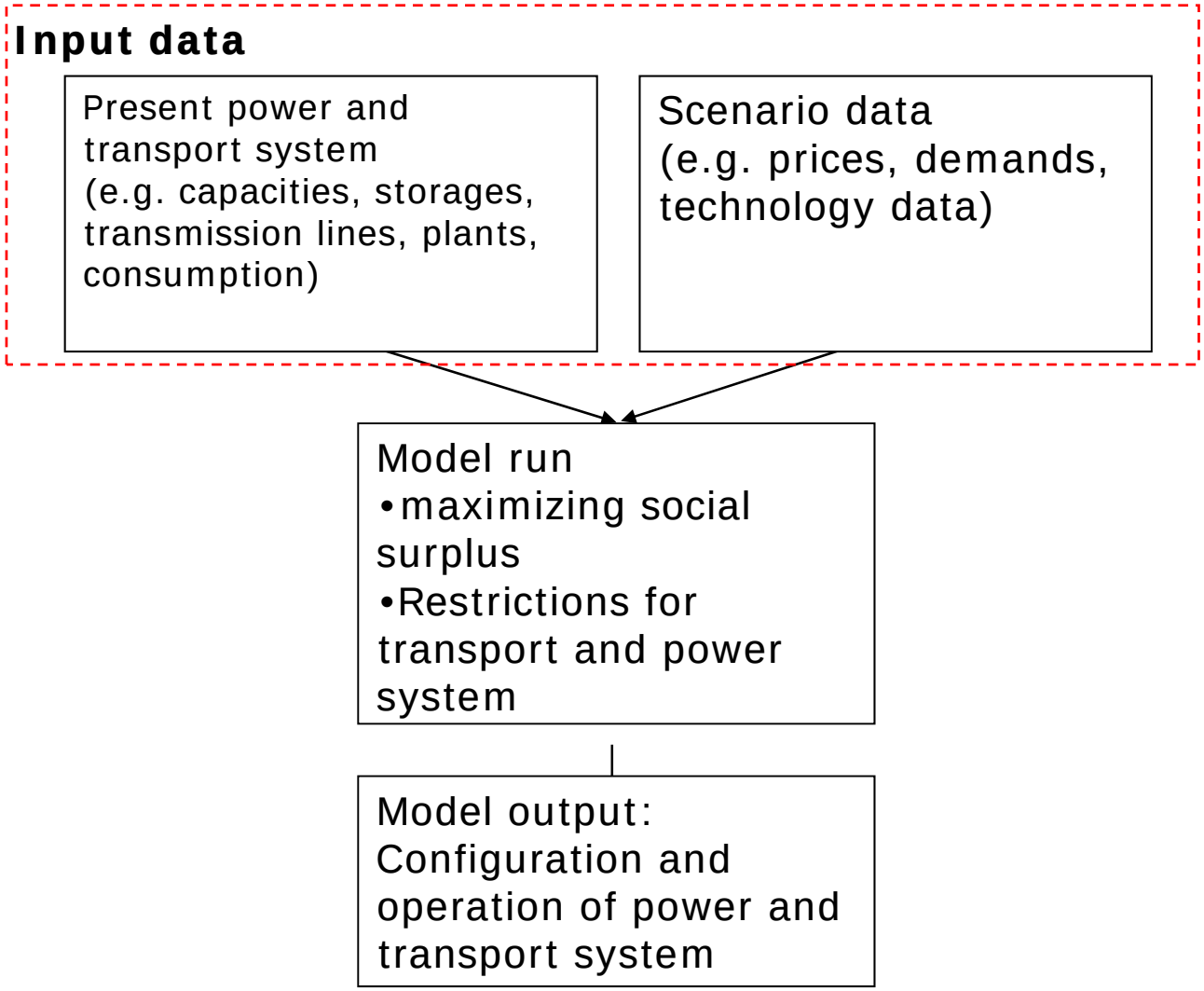
# Purpose

- Adding transport to a power system model (Balmorel) enables analysis of:
- consequences of possibility of using electric power in transport sector
- consequences of adding vehicle-to-grid technologies
- competition between different vehicle technologies

# Balmorel (www.balmorel.com)

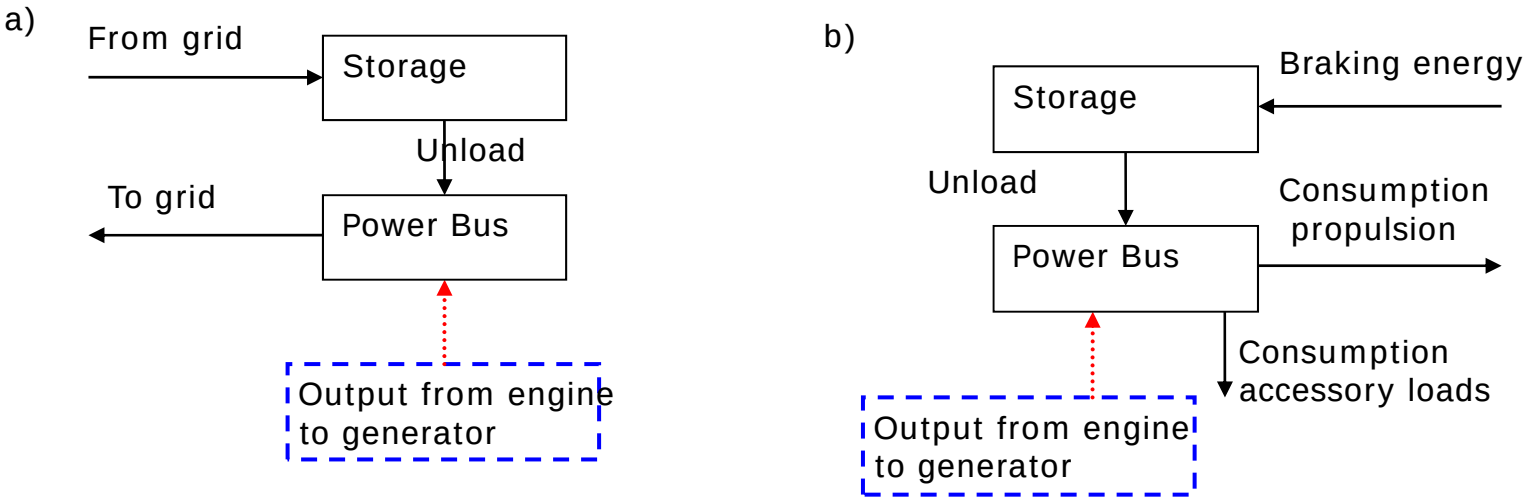
- Investment model: calculates optimal future configurations of power systems
- Power plants, CHP plants, boilers, heat pumps, electricity and heat storages, transmission lines
- Lately:
  - hydrogen storage, production (electrolysis, steam reforming), consumption

# Sketch of the Balmorel model including transport



# Power flow

- Power flow model of electric drive vehicles




Applicable for PHEVs propulsion systems

Replaced with output from fuel cell for FCEVs

a) vehicles plugged in b) vehicles not plugged in

## Model formulation

- Objective function: investments in vehicles
- Vehicle restrictions: balancing of on board storage (plugged in)
  balancing of the power bus (plugged in)
  transport supply and demand must meet
  minimum and maximum capacities
- Electricity balance equation: power to grid - power from grid

## Assumptions

- Communication system in place
- Vehicles are aggregated in vehicle groups
- Average driving patterns (forcing specific patterns for use of diesel)
- All vehicles leave grid with full storage
- Energy consumption of accessory loads and propulsion power proportional to vehicle kilometre driven
- PHEVs and FCEVs are assumed to use the electric motor until storage is depleted

## Case description

- Denmark, Finland, Germany, Norway and Sweden with transmission possibilities among these countries
- 7 selected weeks with hourly resolution (7 X 168 time steps)
- Year 2030
- Oil prices $120/barrel (base), $90 (low), $130 (high)
- Constant fossil fuel price elasticities to oil
- $CO_2$ prices 40€/ton (base), 10€/ton (low), 50€/ton (high)
- Including ICE, BEV, PHEV for persons transport

# Case description

**Vehicle technology investment options**

| Type of vehicle | Annualised inv costs (€) | O & M costs (€/year) | Electric storage cap. (kWh) |
|---|---|---|---|
| ICE | 1,065 | 1,168 | 0.8 |
| BEV | 1,513 | 1,101 | 50 |
| PHEV | 1,484 | 1,168 | 10 |
| FCEV | 1,893 | 1,101 | 10 |

Medium and high wind targets (MW)

| Wind target | Denmark | Sweden | Norway | Finland | Germany |
|---|---|---|---|---|---|
| Medium | 7,291 | 10,000 | 5,980 | 3,200 | 54,244 |
| High | 8,020 | 17,000 | 11,970 | 6,000 | 63,587 |

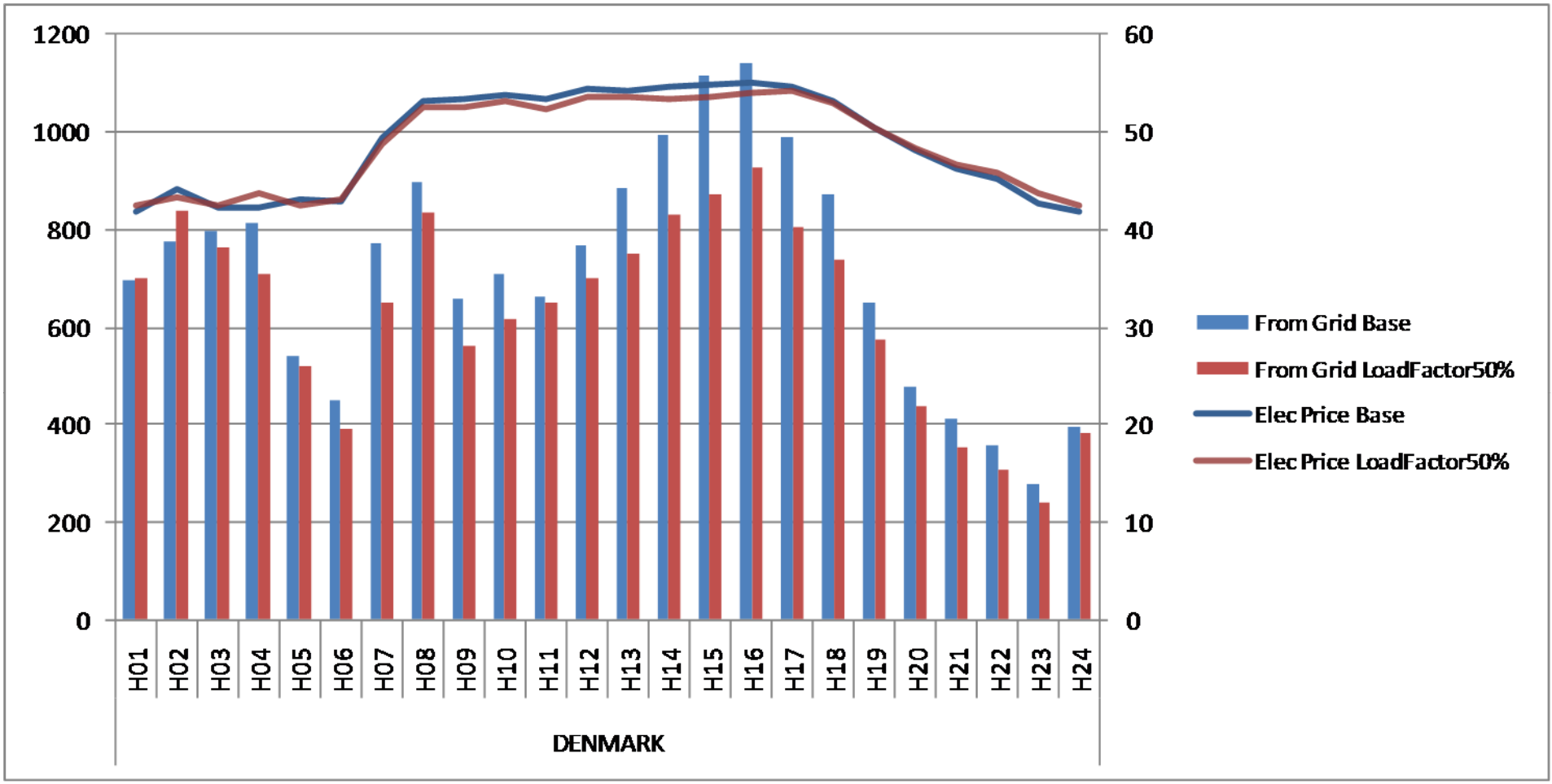
# Case description

- Investment options in power system:
  - Onshore wind
  - Offshore wind
  - CHP plant biomass
  - Open cycle gas turbine
  - Heat storage
  - Solid oxide electrolysis
  - Heat pump
  - Electric boiler
  - Combined cycle natural gas
  - Hydrogen storage, cavern

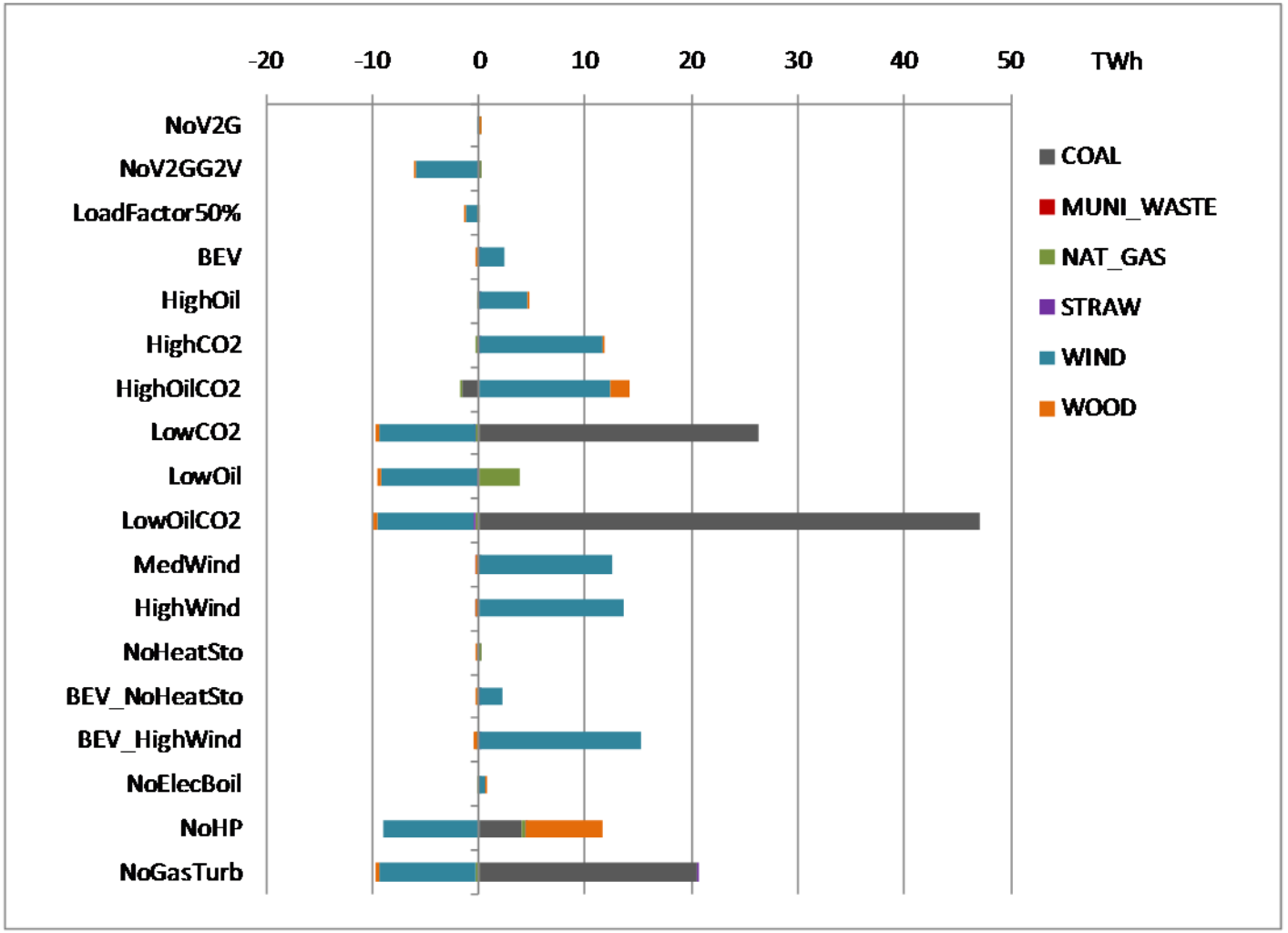
# Results

- Vehicles investments:
  - ICEs in low oil scenarios
  - PHEVs in all other scenarios

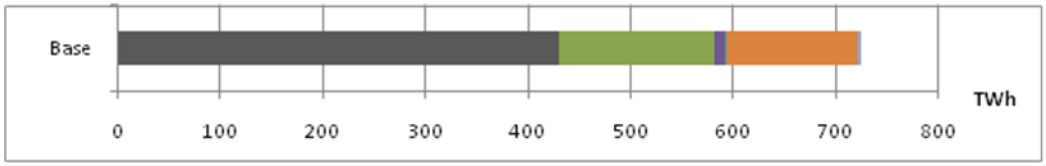
# Charging of EVs distributed on hours during the day

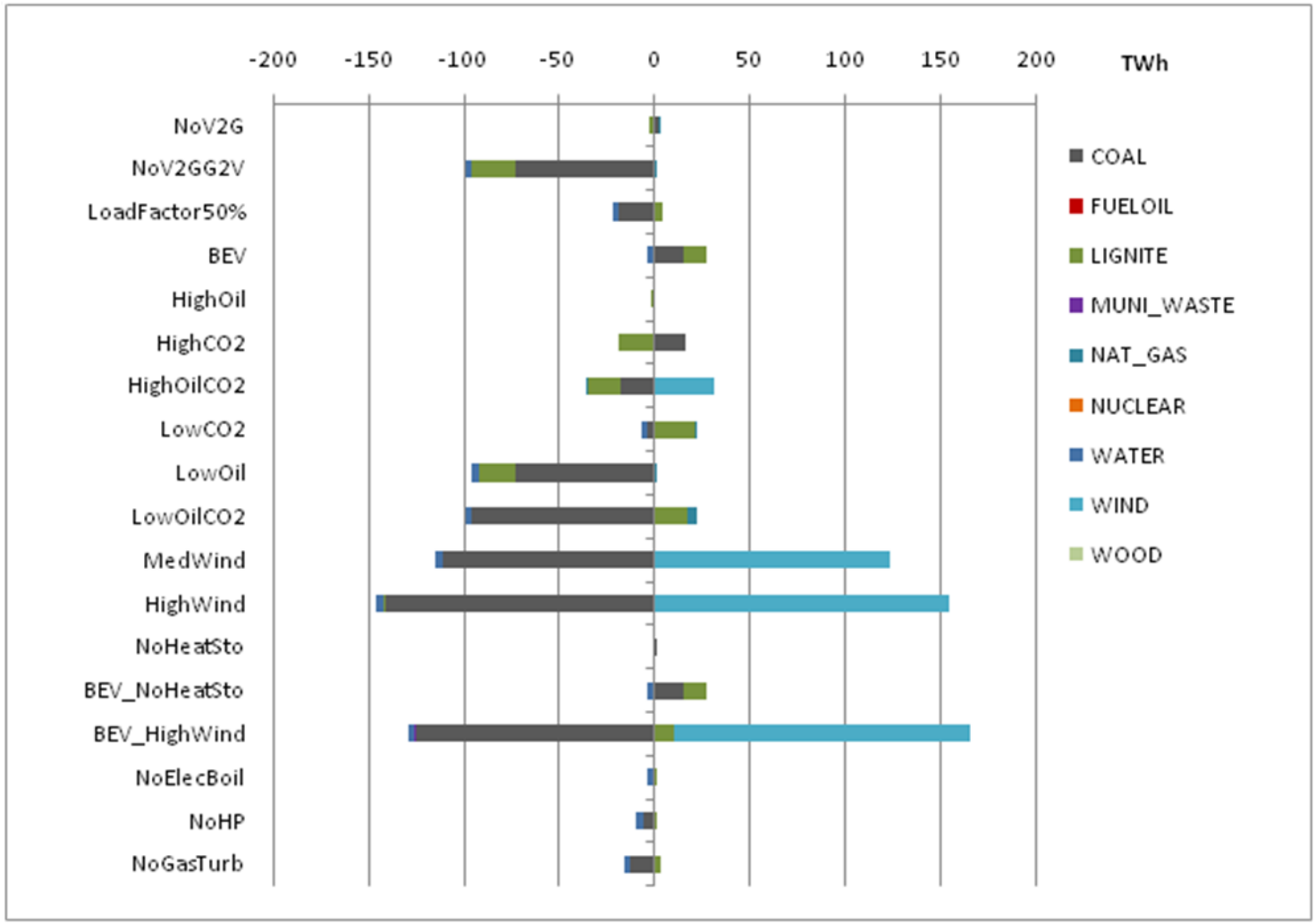


# Denmark: Yearly electricity production on fuel type

# Germany: Yearly electricity production on fuel type



# Conclusions

- PHEVs are very competitive across many scenarios compared to ICEs and BEVs
- Co-optimisation of vehicle and power system investments yields interesting results
- More work needed on requirement to leave the grid with full batteries
- Sustainability of EVs depend on development in surrounding power system:
  - EVs drive on wind power in DK and on coal and lignite in D
  - BUT: CO2 emission market might handle that issue